Technical Note

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A. Sotiropoulos

Radiometric Feed
for Haystack

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Lincoln Laboratory

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

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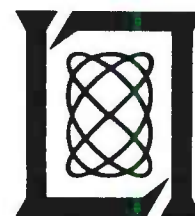
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

LINCOLN LABORATORY

RADIOMETRIC FEED FOR HAYSTACK

A. SOTIROPOULOS

Group 61

TECHNICAL NOTE 1965-23

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ABSTRACT

This technical note describes a series of radiometric feeds in the 5.0 Gcps, 8.0 Gcps and 15.5 Gcps bands which were constructed and installed into the Haystack Cassegrain antenna system. Measured data are presented and also used to calculate the percentage of power intercepted by the sub-reflector and also the Cassegrain antenna aperture efficiency.

Radiometric Feed for Haystack

I.   INTRODUCTION

The Haystack Radio Astronomy experiments require a series of radio-metric primary feeds in the 5.0 Gcps, 8.0 Gcps and 15.5 Gcps bands, linearly polarized and capable of continuous polarization rotation. It is also desirable to illuminate the Cassegrain antenna subreflector with a field distribution which is identical in the principal planes. Symmetrical principal plane patterns can be obtained with a horn feed; however, the large aperture necessary could result in a long bulky feed which would be difficult to construct and to locate in the Haystack equipment shelter room. The desirability for a series of compact feeds which could be easily interchangeable was stressed by the Radio Astronomers.

A simple solution is a paraboloid with a rotating rear feed horn from which polarization information is readily obtainable. Clavin[1] has developed a rear feed which has nearly equal principal plane radiation patterns, low-back radiation and the energy in the cross polarized field is small. It is the purpose of this paper to describe the Clavin feed, present measured data and show calculations of primary beam and Cassegrain antenna aperture efficiencies from the measured data.

II.   DISCUSSION

The feed described by Clavin consists of two complementary sources with

the appropriate amplitude and phase of excitation such that the resultant radiated beam possesses a nearly circular cross section. These sources are complementary because they consist of a waveguide fed dipole and a slot radiator which are polarized in the same direction. The slot is parasitically excited by the dipole. As a consequence of the complementary characteristics, the E-plane radiation pattern of a dipole and the H-plane radiation pattern of a slot are similar; conversely, the H-plane radiation pattern of the dipole and the E-plane radiation pattern of the slot are also similar. When such a feed is used to illuminate a paraboloid the secondary pattern will, in general, also possess identical E- and H-plane patterns and a circular cross-section beam.

In this design the narrow dimension of the waveguide feed was reduced to one-quarter height and matched to standard waveguide with a two-section, quarter wavelength matching transformer. A hole was placed through the broad walls along the centerline of the waveguide and then a teflon bead supporting a dipole was centered in this hole. The electroforming technique was employed in the construction of this waveguide feed. The slot was approximated by placing a copper cylinder around the waveguide in close proximity to the dipole. The cylinder which is terminated by a shorting plate and the waveguide feed simulate a pair of slots positioned on either side of the waveguide. The final configuration of cylinder length, diameter and its positioning from the teflon bead supported dipole was obtained empirically. Rotation of

the polarization was obtained by the incorporation of a rotary joint constructed so that it supports the electroformed waveguide feed. Figure 1 depicts this assembly.

III. MEASUREMENTS

The primary feed geometry of $f/D = .250$ was chosen to maximize the power intercepted by the reflector. Reference to the Haystack Cassegrain geometry, shown in Fig. 2, depicts the subtended angle of the hyperboloid subreflector to be 13.4°. It is this angle that is used to determine the aperture sizes necessary for illuminating the subreflector with a 10 db edge taper for the 8.0 Gcps and 15.5 Gcps frequencies and a 12 db taper for the 5.0 Gcps feed. The paraboloid diameter and design illumination taper with their measured values are shown below.

Frequency	Paraboloid Diameter	Measured Gain	Design Taper	Measured Taper
5.0 Gcps	27 inches	27.7 db	-12 db	-12.6 db
8.0 Gcps	16 inches	27.1 db	-10 db	-12.4 db
15.5 Gcps	8 inches	27.0 db	-10 db	-10.8 db

The optimization of parameters was performed at the designated frequencies of 5.0 Gcps, 7.75 Gcps and 15.375 Gcps. Measured antenna patterns, on-axis gain and impedance for all these feeds are in close agreement with each other. Antenna patterns and measured impedance for all these feeds are shown in Figs. 3 through 12.

IV. EFFICIENCIES

The measured data was used to compute the beam and Cassegrain antenna aperture efficiencies and are described below.

The fraction of power intercepted by the subreflector, the beam efficiency, was calculated using the measured gain (G) and integrating the measured pattern.

The expression for gain and the method used for calculating the beam efficiency is as follows. Assuming circular symmetry about the axis of the beam, the gain of the feed, G, is given by:

$$G = \frac{4\pi}{2\pi \int_0^\pi E^2 \sin\theta \, d\theta}$$

and the fraction of power, ζ, intercepted by the hyperboloid is given by

$$\zeta = \frac{\int_0^{6.7°} E^2 \sin\theta \, d\theta}{\int_0^\pi E^2 \sin\theta \, d\theta}$$

where 6.7° is one-half the angle subtended by the subreflector at the feed.

$$\zeta = \frac{G}{2} \int_0^{6.7°} E^2 \sin\theta \, d\theta$$

Calculated values of ζ for five separate feeds yielded answers ranging from

66 percent to 72 percent.

Next, the aperture efficiency[2] (η) of the Haystack Cassegrain antenna was calculated from the following expression and again assuming a circular beam cross section.

$$\eta = 16 \left(\frac{f}{D}\right)^2 M^2 G_f(o) \left[\int_o^{6.7°} E(\gamma) \tan\frac{\gamma}{2} d\gamma \right]^2$$

where

$G_f(o)$ = on-axis gain of primary feed

M = magnification factor of Haystack geometry

$\frac{f}{D}$ = focal length to diameter ratio of Haystack paraboloid

$E(\gamma)$ = voltage distribution of primary feed

γ = primary feed angle taken from focal axis

Calculations for these feeds yielded values of efficiency (η) from 56 percent to 63 percent. Differences are attributed to errors in the measurements and the integration of measured patterns. This aperture efficiency η does not take into account losses due to aperture block, errors in the surface of the subreflector and the 120-foot paraboloid. Losses due to the 150-foot-diameter radome are appreciable ($\approx$ 1. 2 db at 8 Gcps) but have not been included in this calculation.

Antenna patterns of these feeds are shown in Figs. 6 through 12.

Figures 3 through 5 show plots of admittances for the feeds when completely assembled. Photographs of the feeds during various stages of assembly are shown in Figs. 13 through 18.

V. CONCLUSION

A series of feeds in the 5.0 Gcps, 8.0 Gcps and 15.5 Gcps bands have been described which are identical in design and performance. These feeds are easily interchanged, i.e., measurements could conceivably be made in two or three different bands in the same day. The measured beam efficiency of 70 percent has been compromised in order to obtain the desirable characteristics of compactness, identical design through the three bands, and a relatively simple method of rotation of the polarization.

VI. ACKNOWLEDGMENT

The author wishes to acknowledge Dr. John Ruze for the suggestion of using the Clavin feed.

REFERENCES

1. A. Clavin, "A New Antenna Feed Having Equal E- and H-Plane Patterns," IRE, PGAP, AP-2, No. 3, 113-119 (July 1954).

2. A. Dion, "The Aperture Efficiency of Some Horn-Fed Paraboloidal Reflectors," Group Report 61G-3, Lincoln Laboratory, M.I.T. (30 December 1963).

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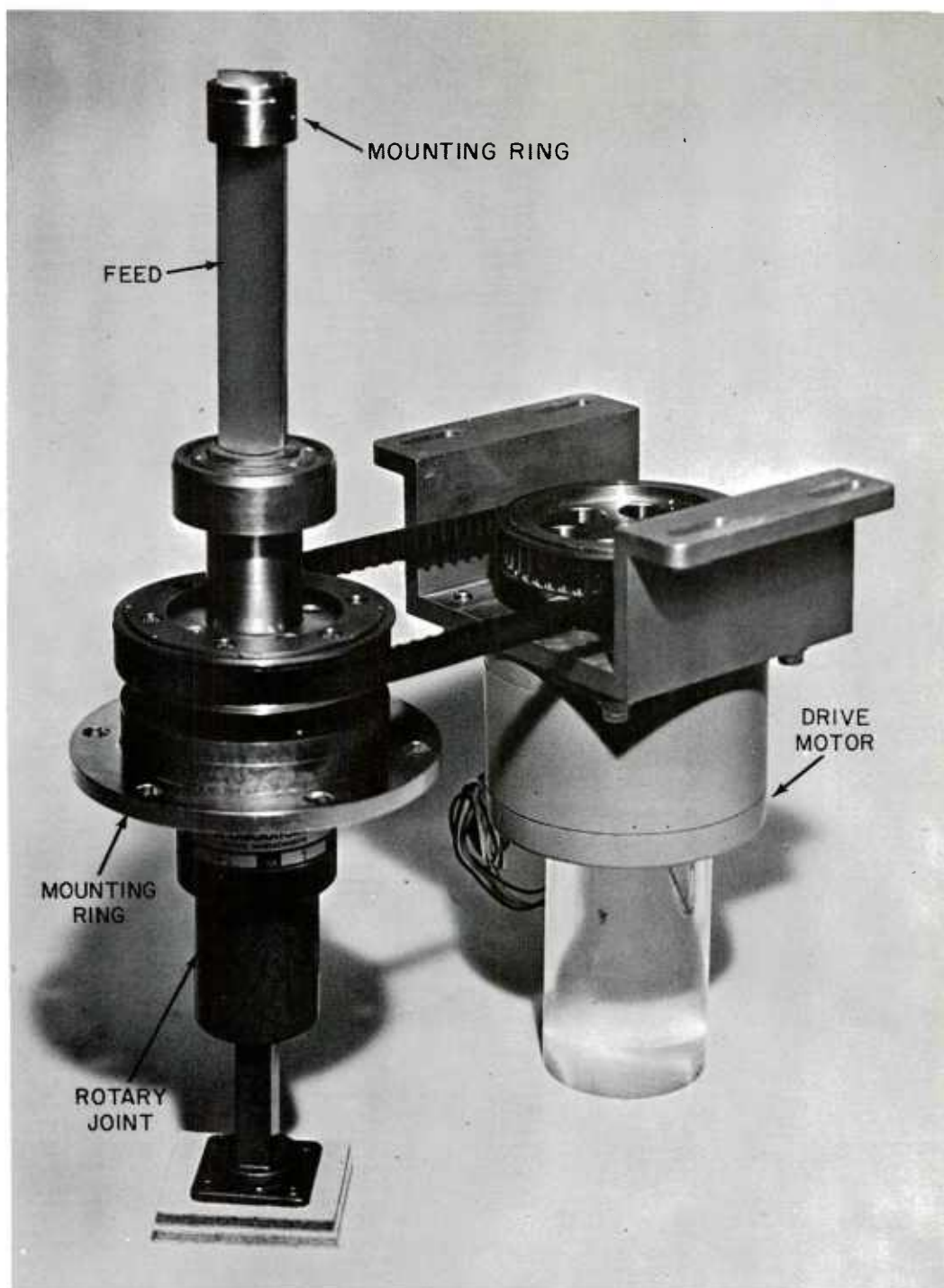
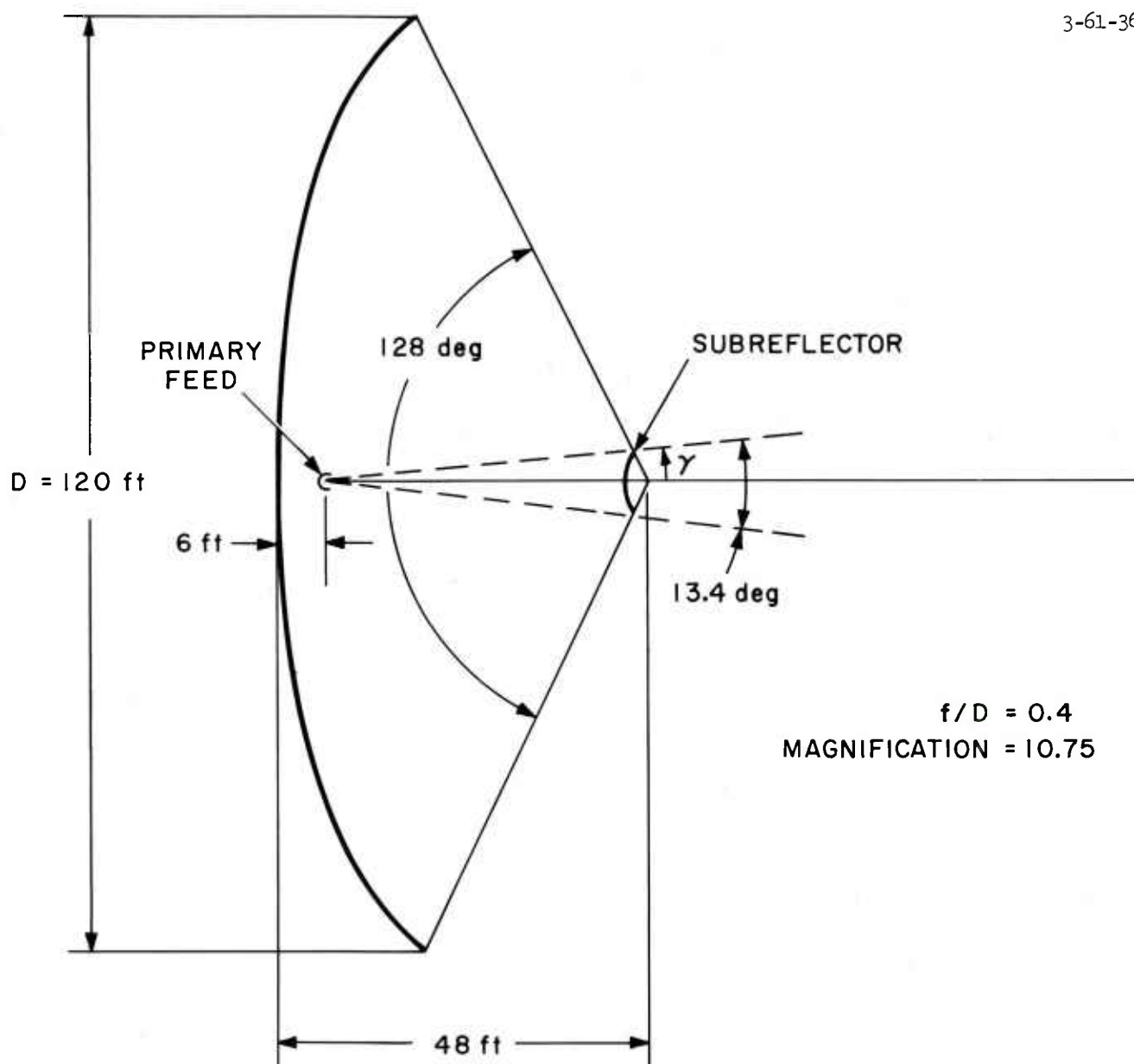Fig. 1. 8.0 Gcps feed assembled to rotary joint with drive unit.
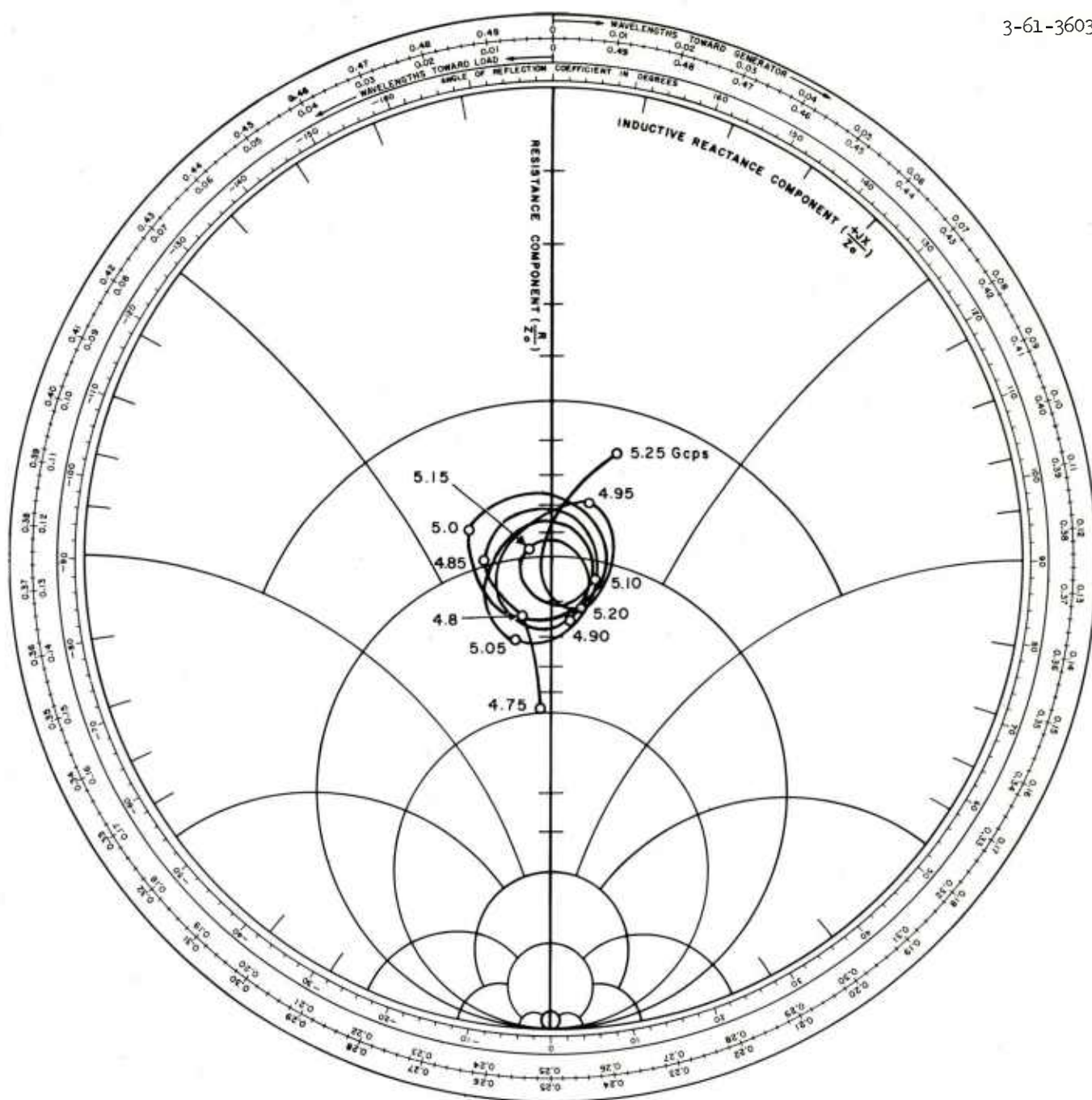
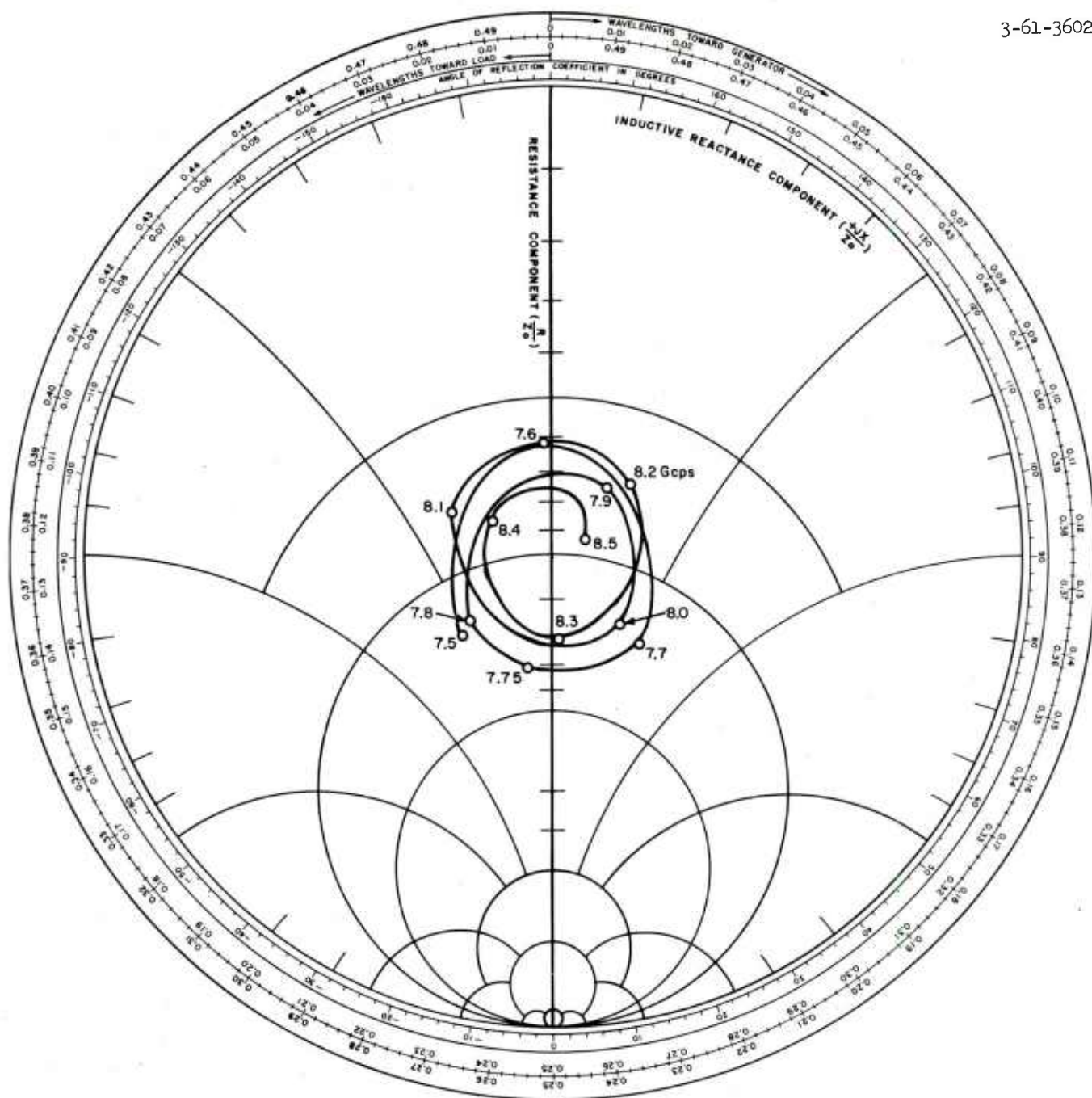Fig. 2. Haystack Cassegrain geometry.

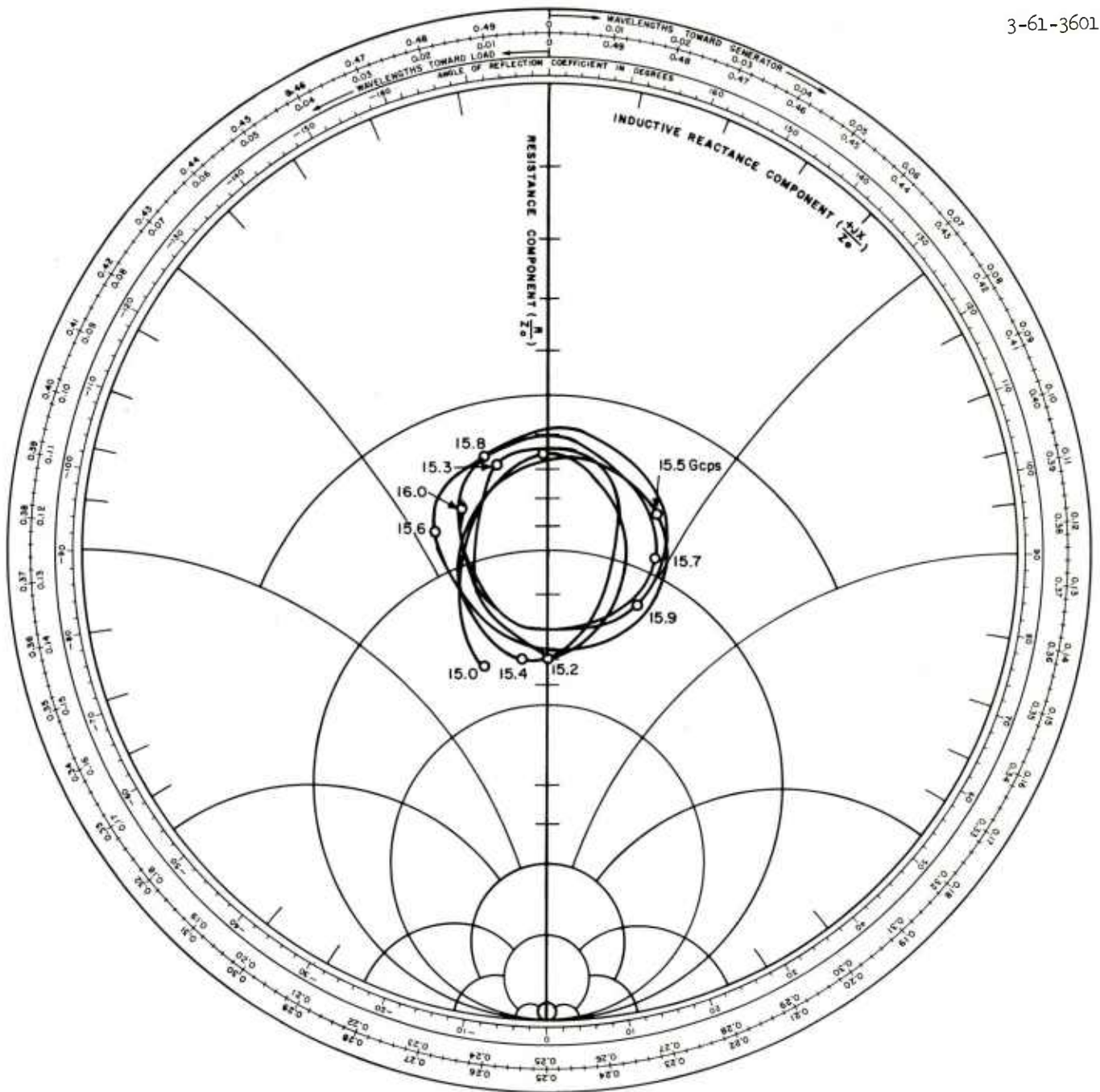Fig. 3. 5.0 Gcps feed admittance.

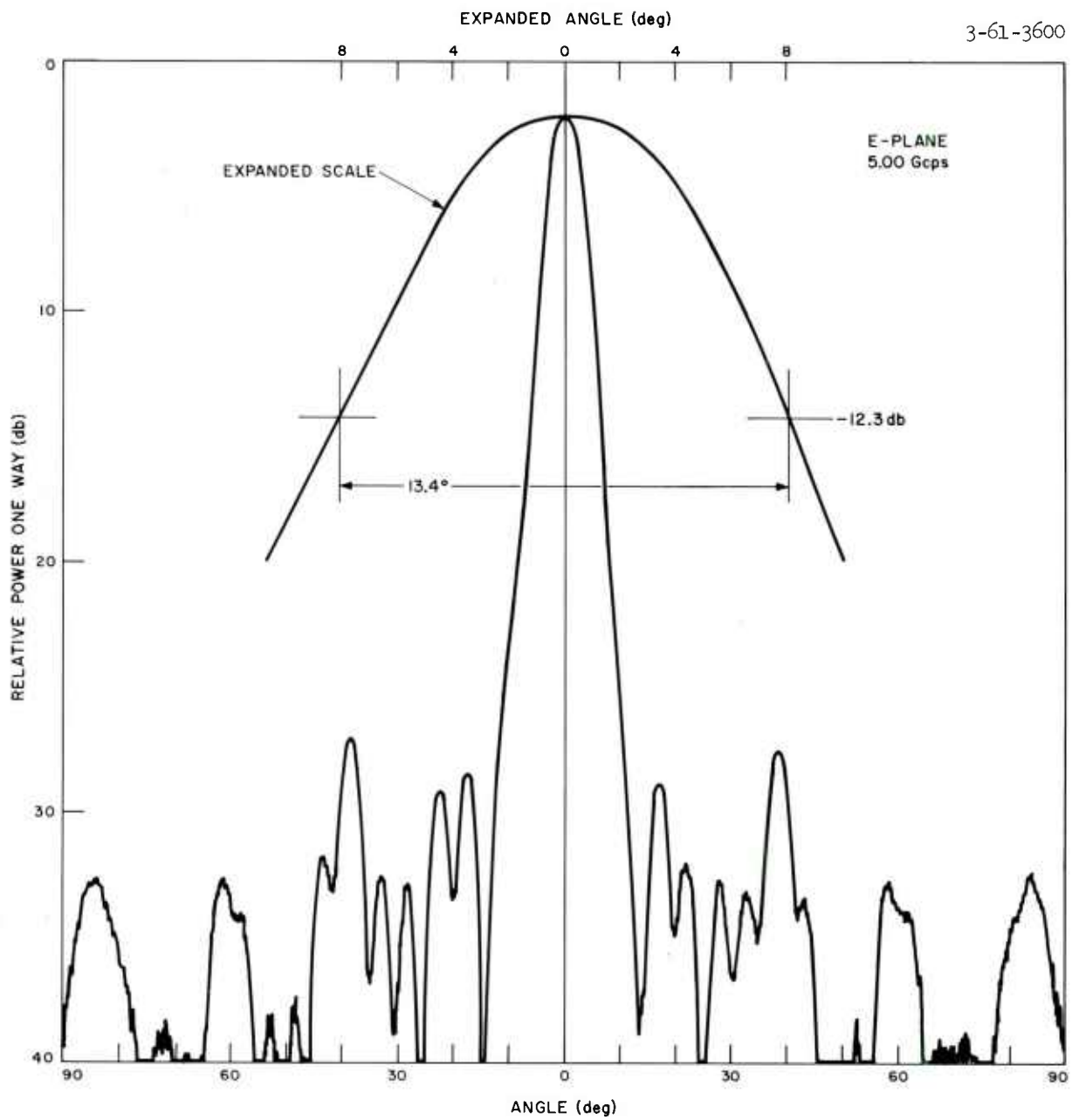Fig. 4. 8.0 Gcps feed admittance.

Fig. 5.   15.5 Gcps feed admittance.

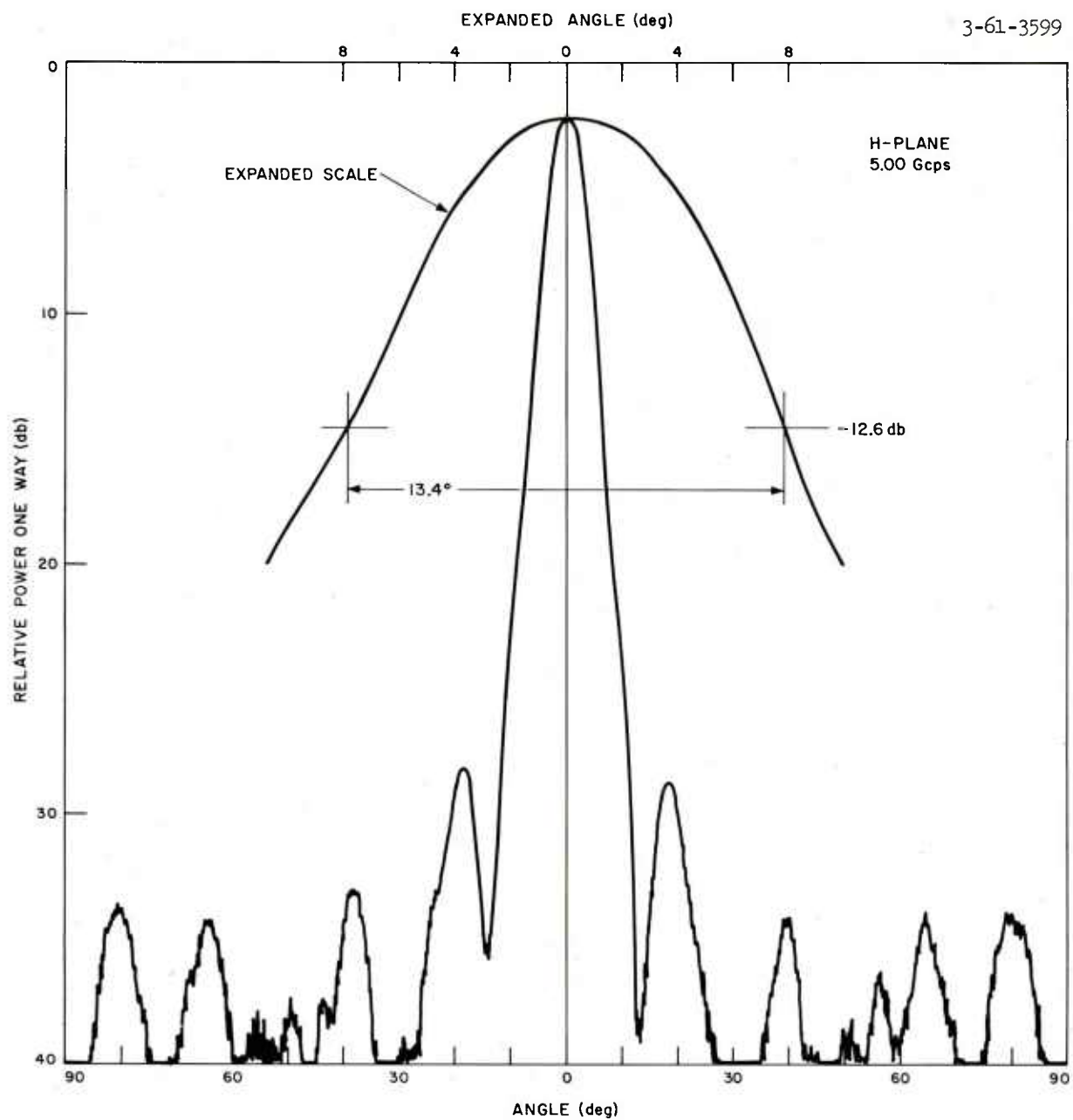12

Fig. 6. Antenna pattern 5.0 Gcps E-plane.

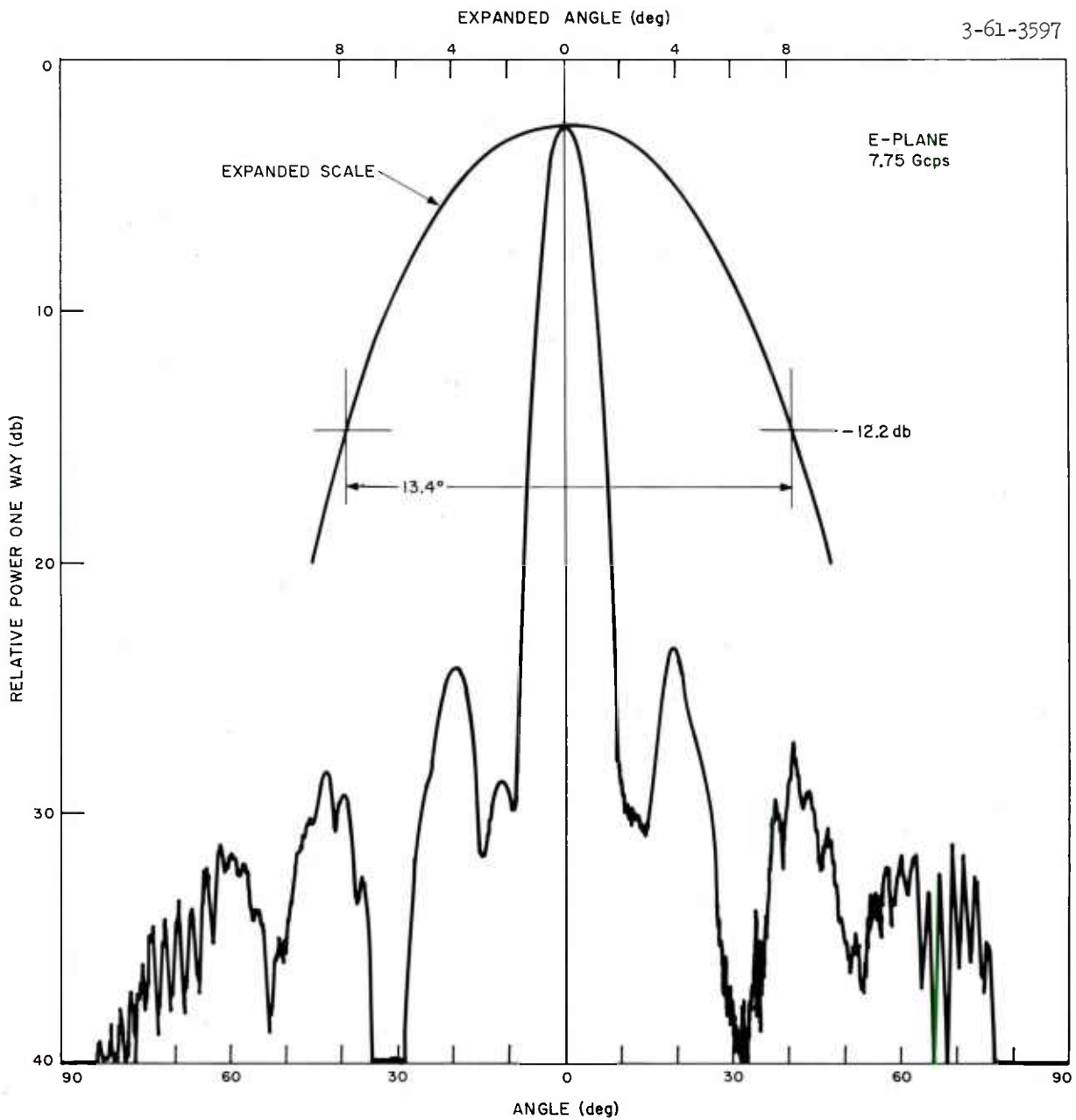Fig. 7. Antenna pattern 5.0 Gcps H-plane.

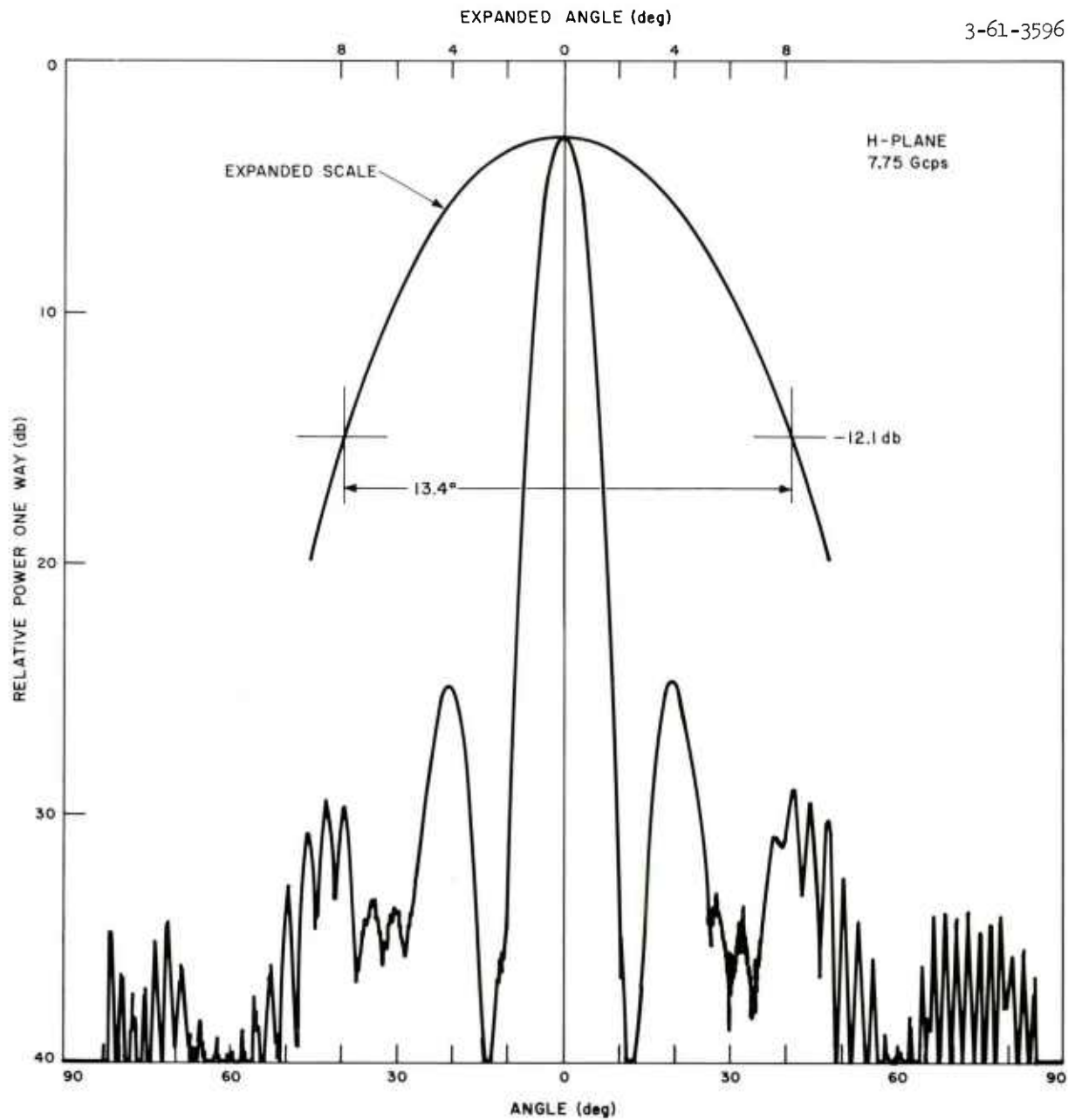Fig. 8. Antenna pattern 7.75 Gcps E-plane.
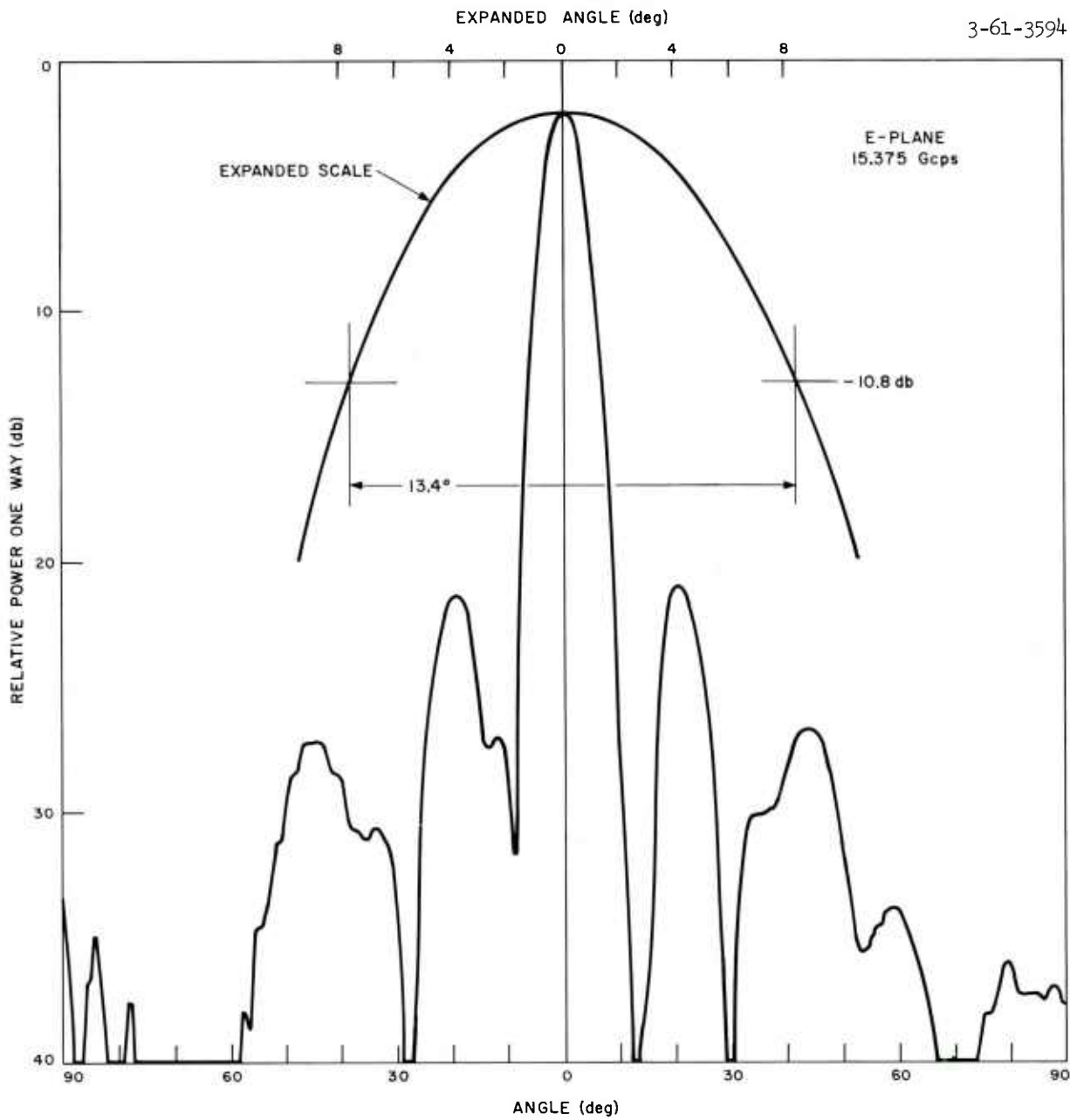
Fig. 9. Antenna pattern 7.75 Gcps H-plane.
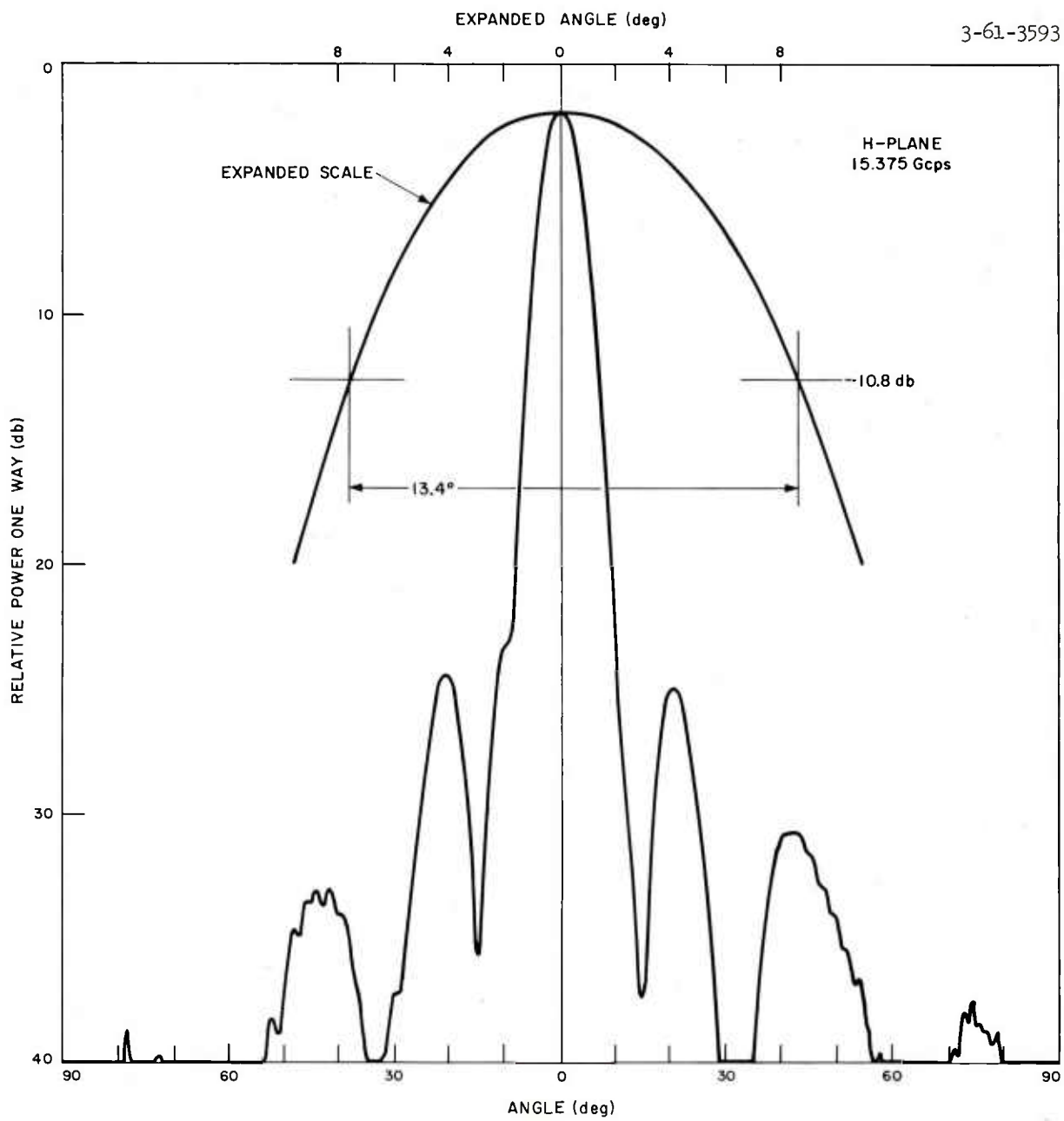
Fig. 10. Antenna pattern 15.5 Gcps E-plane.

Fig. 11. Antenna pattern 15.5 Gcps H-plane.

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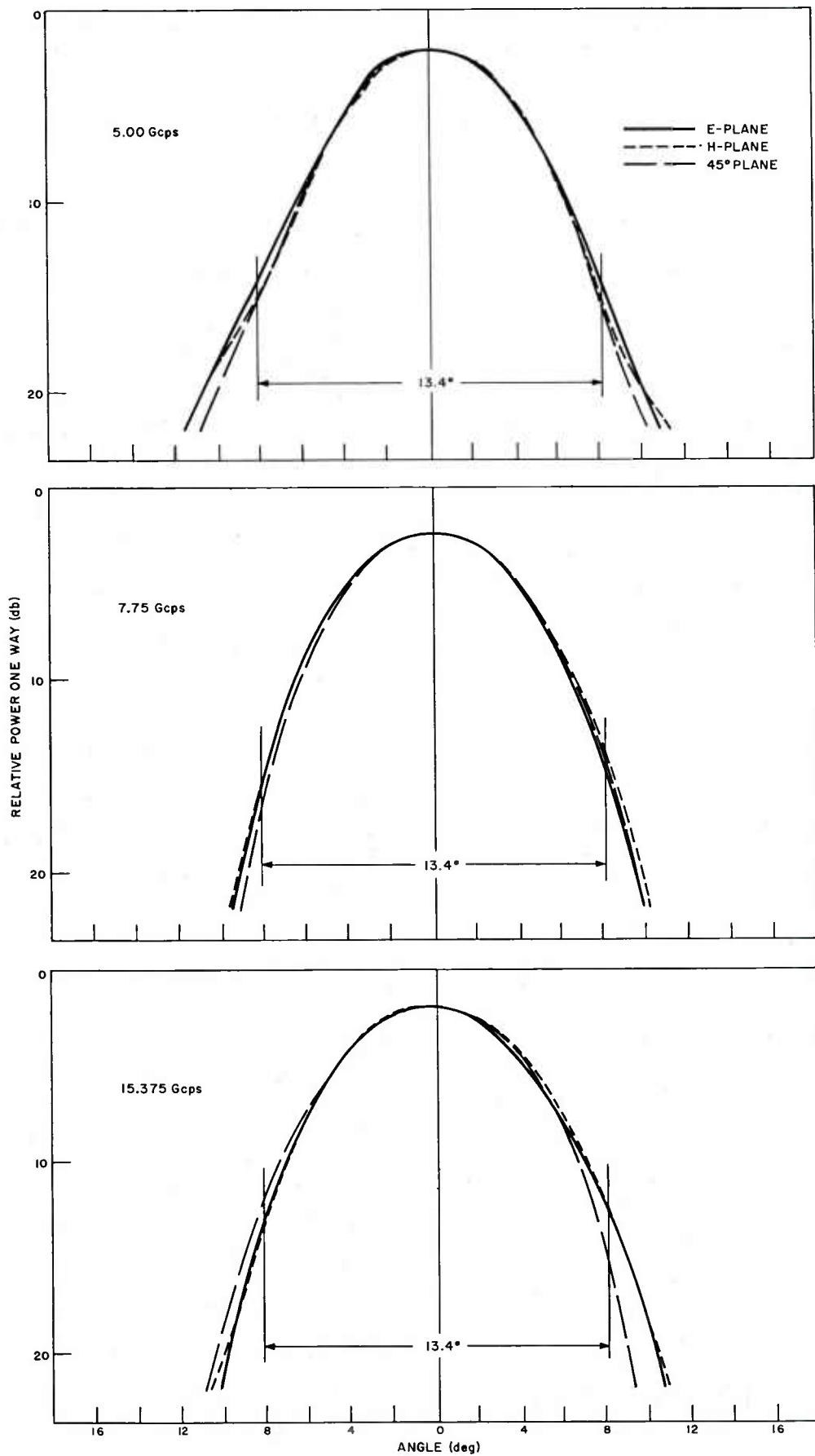Fig. 12. Antenna pattern comparisons of measured principal and 45°
planes of the 5.0 Gcps, 7.75 Gcps and 15.375 Gcps feeds.

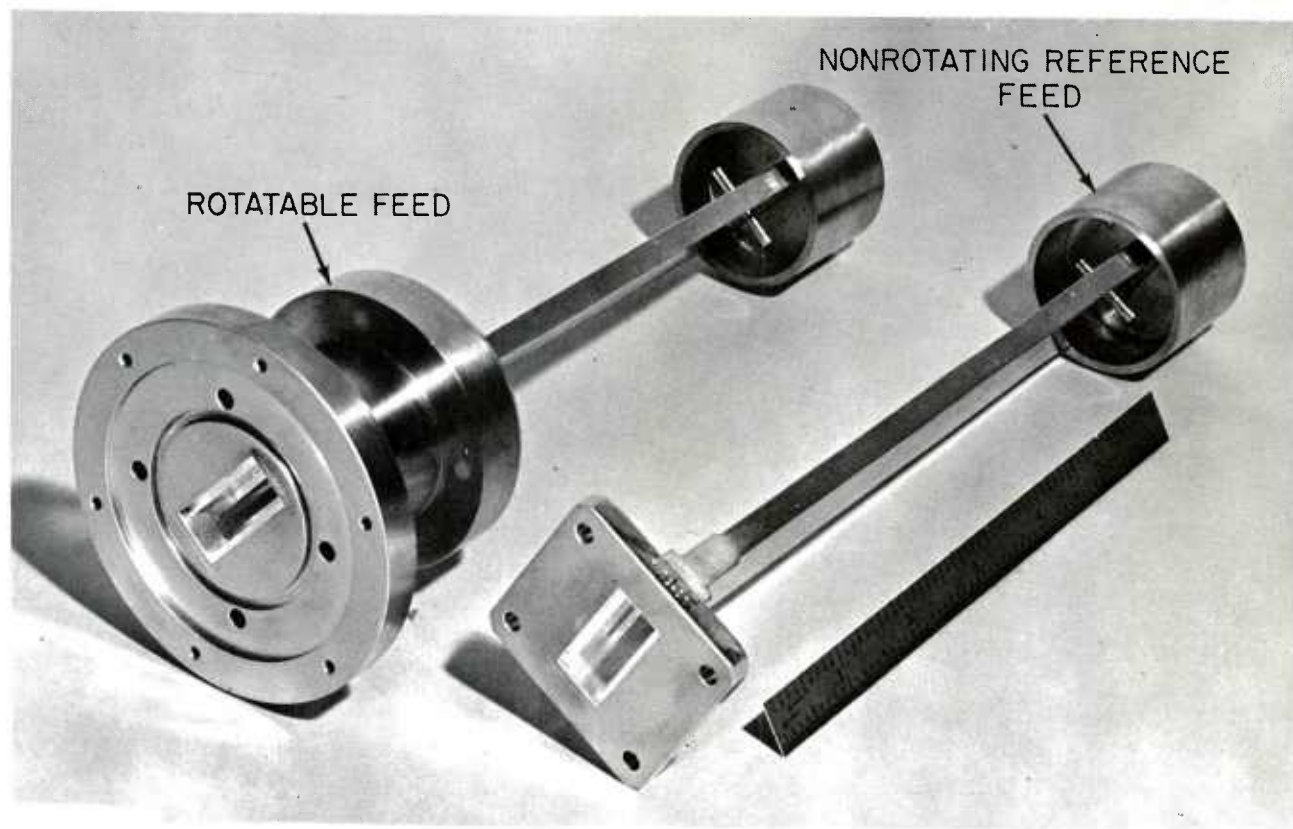ROTATABLE FEED

NONROTATING REFERENCE FEED
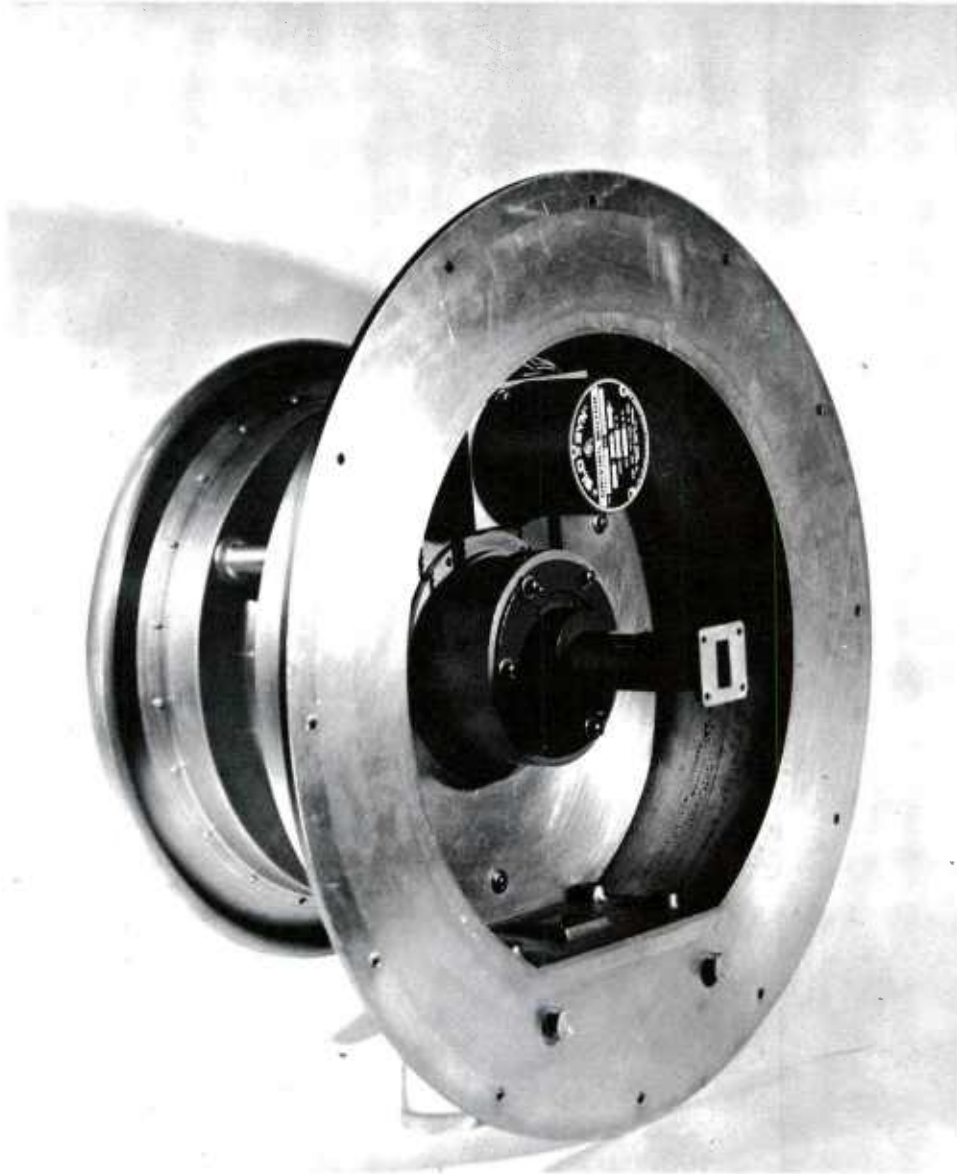
Fig. 13. 8.0 Gcps waveguide feeds.

Fig. 14. Rear view of 8.0 Gcps assembled feed.

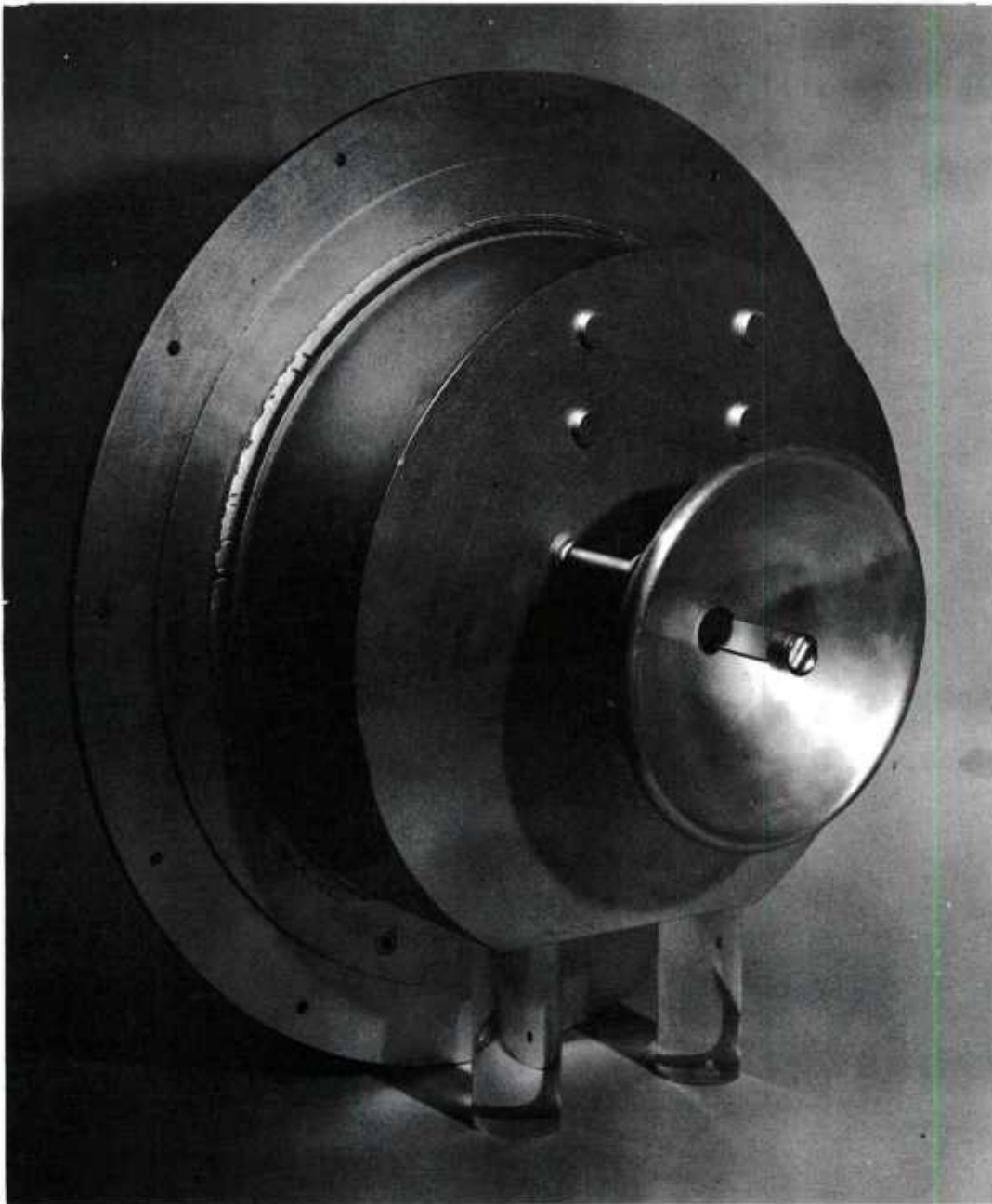Fig. 15. 8.0 Gcps feed shown with side mounted reference antenna.
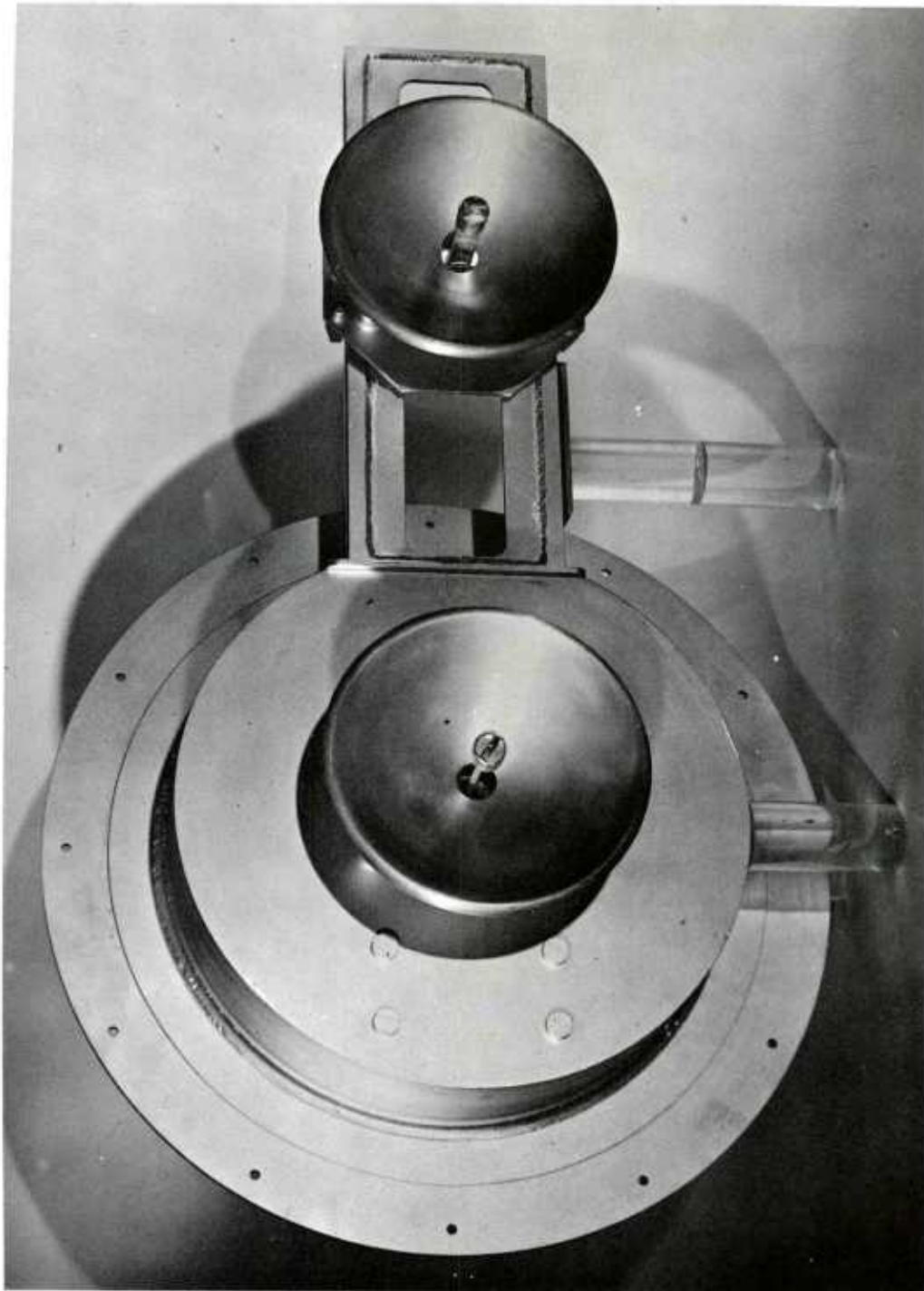
Fig. 16. Front view of assembled 15.5 Gcps feed.

Fig. 17. 15.5 Gcps feed shown with side mounted reference antenna.

Fig. 18. 5. 0 Gcps feed assembled to its mounting structure.

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13. ABSTRACT

This technical note describes a series of radiometric feeds in the 5.0-, 8.0-, and 15.5-Gcps bands which were constructed and installed into the Haystack Cassegrainian antenna system. Measured data are presented and used to calculate the percentage of power intercepted by the subreflector, and also the Cassegrainian antenna aperture efficiency.

14. KEY WORDS

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